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The edible African giant snails : fertility of *Achatina achatina* (Linné, 1758), *Achatina fulica* (Bowdich,1820) and *Archachatina ventricosa* (Gould,1850) in humid forest; influence of animal density and photoperiod on the fertility in breeding

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KEYWORDS: Achatinidae, edibile African snails, Côte d'Ivoire, breeding.

ABSTRACT Breeds *Achatina achatina* (Linné), *Achatina fulica* (Bowdich) and *Archachatina ventricosa* (Gould) were collected in forests around Adzopé and Miadzin at 100 km in the North-east of Abidjan in Côte d'Ivoire. Their fertility was studied in forest by the method of release followed by the capture and the autopsy of uteruses. The influence of three densities (50 snails / mμ; 100 snails / mμ and 200 snails / mμ) and two photoperiods (12 hours daylight / 12 hours dark and 0 hours daylight / 24 hours dark) on the parameters of fertility was studied in breeding. In forest, the fertility obtained by *Achatina fulica* (Bowdich) is 50 % of ovigerous snails and 109 eggs per breeder; by *Achatina achatina* (Linné) , 42,25 % of ovigerous snails and 101 eggs per breeder and by *Archachatina ventricosa* (Gould), 17,08 % of ovigerous snails and 2 eggs per breeder. In breeding, the parameters of fertility decrease when the animal density increases. However the best parameters of fertility are obtained in the density of 50 snails / mμ with the photoperiod 12 hours daylight / 12 hours dark. In the aroused conditions, *Achatina fulica* (Bowdich) presented the best parameters of fertility, and was thus found to be the most prolific of the species.

RIASSUNTO In Africa occidentale, ed in particolare in Costa d'Avorio, i molluschi terrestri costituiscono una tradizionale risorsa alimentare, ricca di proteine. Le specie che più vengono utilizzate a scopo alimentare appartengono ai generi *Achatina* e *Archachatina*, presenti in tutte le zone ricche di foreste, dalla Guinea alla Nigeria. Purtroppo, a causa della distruzione progressiva del loro habitat naturale ad opera dell'uomo, unitamente all'intenso sfruttamento a scopo alimentare, alcune specie si sono estremamente rarefatte. Oggigiorno, lo sviluppo di nuove metodiche di allevamento delle specie si è ormai reso necessario al fine di mantenere disponibile questa fonte di proteine per la popolazione. Nel presente lavoro, per poter individuare quale delle specie disponibili nell'area fosse la più adatta ad essere allevata, sono state studiate *Achatina achatina* (Linné), *Achatina fulica* (Bowdich) ed *Archachatina ventricosa* (Gould). Molti esemplari delle tre specie sono stati raccolti nelle foreste intorno alle località di Adzopé e Miadzin, circa 100 Km a nord-est di Abidjan (Costa d'Avorio). Dopo la marcatura della conchiglia con vernice, gli esemplari sono stati rilasciati nel loro ambiente naturale per poi essere nuovamente ricatturati. La fertilità di questi esemplari è stata valutata attraverso lo studio delle gonadi. Su altri esemplari, mantenuti in cattività, è stata valutata l'influenza di tre diverse densità/m² (50, 100 e 200 molluschi/mμ) e due fotoperiodi (12 ore di luce/12 ore di buio e 24 ore di buio) sui parametri di fertilità. *A. fulica* è risultata essere la specie più prolifica sia in natura che negli esemplari allevati e viene quindi indicata come la più adatta ad essere allevata a scopo alimentare.

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INTRODUCTION

In West Africa, and particularly in Côte d'Ivoire, snails are traditionally consumed in the forest zone, where they are an important source of proteins (Beckett, 1944; Waitkuwait, 1987; Ba, 1994; Aboua et Boka, 1996; Otchoumou, 1997). These snails belong to two genera: the genus *Achatina* and the genus *Archachatina*. They can be found all over the West - African forested zone, from Guinea to Nigeria. Most often, consumed and/or marketed snails are collected in the wild during the rainy seasons. The destruction by man of their natural biotope, the dense forest, and the frequent collection lead to the scarcity of some species. Thus, the development of rearing methods became a necessity. A breeding operation should supply the needs in animal proteins, and provide financial incomes for the population. Several species are candidates for rearing. To choose the most interesting one for rearing, fertility is an important parameter. Thus in this paper, we studied the fertility of three species *Achatina achatina* (Linné), *Achatina fulica* (Bowdich) and *Archachatina ventricosa* (Gould), both in natural conditions(forest) and breeding conditions.

MATERIALS

The Snails Species

The snails used belonged to the *Achatina* genus, with the species *Achatina achatina* (Linné, 1758) and *Achatina fulica* (Bowdich,1820), and the *Archachatina* genus, with the species *Archachatina Ventricosa* (Gould,1850) (Fig. 1). The samples were collected in the humid half- deciduous forests, in the Eastern part of Côte d'Ivoire. The age of the subjects was 12 months, as estimated from curves of linear growth (Hodasi, 1979; Upatham *et al.* 1988).

The forest

This is a deciduous-forest (Aubreville, 1936; Mangenot *et al.*, 1948; Schnell, 1952), hereafter indicated as a humid dense half- deciduous forest. It is a forest of *Mapania sp.* (Cyperaceae) and *Diospyros sp.* (Ebenaceae). The characterizing species are:

-for spices: *Buforrestia mannii* (Commelinaceae); *Ctenitis variabilis* (Polypodiaceae); *Mapania baldwinii* (Cyperaceae); *Mapania coriandrum* (Cyperaceae); *Mapania linderi* (Cyperaceae); *Trichomanes guineense* (Hymenphyllaceae).

Achatina achatina(Linné,1758) *Achatina fulica(Bowdich,1820)* *Archachatina ventricosa(Gould,1850)*

Fig. 1: Presentation of the three species of snails. Fig. 1: Le tre specie di *Achatina* considerate nel presente lavoro

- for lianas: *Eremospatha hookeri* (Palmaceae); *Tetracera potatoria* (Dilleniaceae).
- for trees and herbs: *Diospyros gabunensis* (Ebenaceae); *Diospyros chevalieri* (Ebenaceae); *Drypetes aylmeri* (Euphorbiaceae); *Soyauxia floribunda* (Medusandraceae); *Cephaelis yapoensis* (Rubiaceae).

The Breeding Site

The site was installed in an old cocoa plantation, in the shade of cacao trees. It covered 100 m². In this site, containers were installed on shelves, which were one meter high.

The containers were wooden made. They were 0.60 m long, 0.50 m wide, and 0.30 m high. They were divided in the width side into two containers with a surface area of 0.15 m². One of the containers was covered with a black plastic film, in order to create total darkness inside, whereas the other one received daylight (Fig. 2 A). The litter of the breeding container is constituted by frank earth and by compost in the proportions of 2 / 1. The incubation containers were cylindrical Plexiglas boxes of 4.1 cm beam and 5.2 cm high, with a circular drilled lid of 4.1 cm beam (fig. 2 B). Egg laying nests with a diameter of 2 cm, and 3 cm deep, were made in the litter of the eggs incubation containers. Containers were cleaned every 4 days.

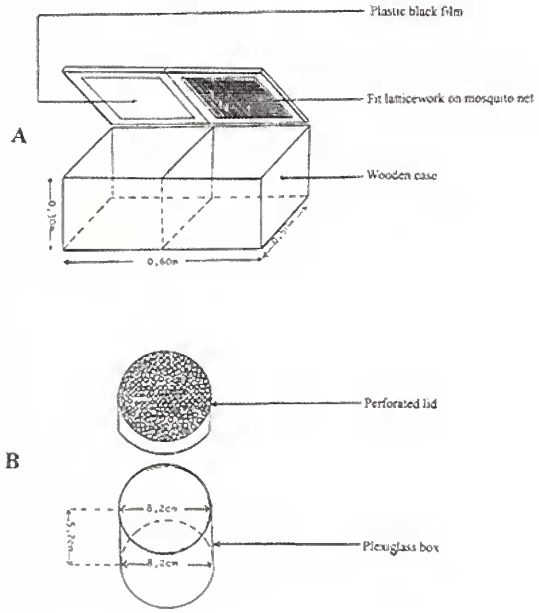

Fig. 2: Snails breeding containers (A) and eggs incubation boxes (B)
Fig. 2: Contenitori per l'allevamento delle *Achatina (A)* e l'incubazione delle uova (B).

METHODS

Forest study

2400 snails (800 by species), were marked with black painting (half posterior of the shell) (fig. 3) and released in the middle of the Miadzin Forest. Every month, 50 snails of each species were captured, sacrificed, dissected and their uterus examined for counting eggs. The monthly rains were measured by means of pluviometer.

REARING EXPERIMENT

Influence of density on the fertility

954 snails were distributed into three densities (50 snails / m²; 100 snails / m² and 200 snails / m²), by species. Every density was repeated six times.

Influence of photoperiod on the fertility

288 snails were distributed in two light regimes (0L:24D and 12L:12D), by species, with a density of 50 snails / m². Every treatment was repeated six times

In rearing conditions, snails were fed ad *libitum* with papaya tree leaves (*Carica papaya* (Caricaceae)) for the following reasons:
- papaya tree leaves are some of the green feeds that snails eat the most;
- chemical analyses of the composition of some green feeds showed that papaya leaves contain much more calcium than lettuce *(Lactuca sativa)*, cabbages *(Brassica oleracea)*, cassava leaves *(Manihot esculentus)* and taro *(Xanthosoma mafaffa)*. Calcium is indispensable for the making of the shell (Otchoumou *et al.*, 1991).

Measures

A Sartorius 1104 balance to the nearest 0.01 mg was used to weigh eggs, food, and snails. An electronic calliper to the nearest millimeter, was used to measure the snail's shells and the dimensions of eggs (big and small diameter).

Every month, the percentage of ovigerous snails, the average number of eggs by uterus, the total number of eggs per species, the total number of eggs laid, the average number of eggs laid

Table 1: Montly forest parameters of fertility. **Tav. 1**: Parametri mensili di fertilità per gli esemplari rilasciati nella foresta.

	Species		
	Achatina achatina	*Achatina fulica*	*Archachatina ventricosa*
Monthly mean number of ovigerous snails on a total of 50	$21^{a}\pm17$	$25^{a}\pm15$	$09^{b}+1$
Monthly mean percentage of ovigerous snails on a total of 50	$42^{a}\pm34$	$50^{a}\pm29$	$17^{a}+12$
Monthly mean number of eggs per snail	$101^{a}\pm45$	$109^{a}\pm1$	$2^{b}+0$

The mean values of the same line indexed the same letters are not significantly differents (P<0.05)

by snails, the duration of the incubation and the percentage of hatching were determined. The food was weighed at the beginning, and the rests were weighed after four (4) days. The mortalities were noted for every month. The food consumption and the cumulated mortality rate were calculated every month.

Table 2: Density influence on reared snails fertility parameters. **Tav. 2**: Influenza della densità sui parametri di fertilità degli esemplari allevati.

		Densities (snail/m²)		
		50	100	200
Total number of laid eeggs	*Achatina achatina*	485^{a}	131^{b}	90^{c}
	Achatina fulica	2692^{a}	412^{b}	0^{c}
	Archachatina ventricosa	23^{a}	0^{b}	0^{b}
Monthly mean number of eggs per snail	*Achatina achatina*	$40^{a}\pm6$	$11^{b}\pm2$	$7^{b}\pm0$
	Achatina fulica	$189^{a}\pm17$	$34^{ab}\pm6$	$0^{b}\pm0$
	Archachatina ventricosa	$2^{a}\pm0$	$0^{a}\pm0$	$0^{a}\pm0$

The mean values of the same line indexed the same letters are not significantly differents (P<0.05)

Statistical analyses

Mean values were computed, with analysis of variance with one factor, for the percentage of ovigerous snails, the average number of eggs per uterus, the total number of eggs per species, the total number of eggs laid, the average number of eggs laid per snails, the duration of the incubation and the percentage of hatching, according to the multiple averages comparison test of Newmann and Keuls (Dagnelie, 1975).

RESULTS

Table 1 shows the results for the monthly parameters of fertility of the breeders in the forest setting. Fertility was higher for *Achatina fulica* (Bowdich) (50 % of ovigerous snails and 109 eggs per breeder), weak for *Achatina achatina* (Linné) (42.25% of ovigerous snails and 101 eggs per breeder) and very weak for *Archachatina ventricosa* (Gould) (17.08 % of ovigerous snails and 2 eggs per breeder). Statistical analysis (Table 1) show that there was a significant difference ($P < 0.05$) between fertility parameters of the genus *Achatina* and the genus *Archachatina*. The curves of influence of the pervading rain levels on the variations of the parameters of fertility (Fig. 4), showed that for the 3 species of snails, the fertility (percentage of ovigerous snails), increased during the rainy season, and fell considerably during the dry season.

Table 2 shows the results of the effect of three densities onto the production of eggs. The average number of eggs per laying, and the total number of eggs per species, decreased when the animal density increased. However, these differences were not significant($p < 0.05$) between *Archachatina ventricosa* (Gould) whereas they were significant for *Achatina achatina* (Linné) and *Achatina fulica* (Bowdich).

Table 3: Effect of photoperiod on ovideposition (50 snails/m²). **Tav. 3**: Effetti del fotoperiodo sull'ovodeposizione (50 esemplari/m²).

		Light regimes	
		12L:12D	OL:24D
Number of oviposition	*Achatina achatina*	7^{a}	2^{b}
	Achatina fulica	23^{a}	7^{b}
	Archachatina ventricosa	5^{a}	1^{b}
Monthly mean number of oviposition	*Achatina achatina*	$1^{a}\pm0$	$0^{a}\pm0$
	Achatina fulica	$2^{a}\pm0$	$1^{b}\pm0$
	Archachatina ventricosa	$0^{a}\pm0$	$0^{a}\pm0$

The mean values of the same line indexed the same letters are not significantly differents (P<0.05)

Results for the effect of two photoperiods on the production of eggs are recorded in Table 3. The 12 L:12D treatment gave three times more egg laying and more eggs than the 0L:24D treatment, for the 3 species studied. It must be noticed that whatever the light regime, fertility parameters were better for *Achatina fulica* (Bowdich) than those for the two other species. There was a significant difference($p < 0.05$) between the treatment 12L:12D and the treatment 0L:24D in terms of fertility parameters, for the three species studied.

Table4: Fertility and reared snails eggs characteristics (50 snails/m²). Tav. 4: Fertilità e caratteristiche delle uova ottenute da esemplari allevati (50 esemplari/m²).

	Snail species		
	Achatina achatina	*Achatina fulica*	*Archachatina ventricosa*
Big diameter(mm)	6±1	4±0	8±0
Small diameter(mm)	4±1	3±0	6±1
egg weight(g)	0.52±0.02	0.17±0.01	1.88±0.24
Mean number of eggs per oviposition	69^{b}±40	117^{a}±40	5^{c}±0
Monthly mean number of oviposition	1^{b}	2^{a}	0^{c}
Monthly mean number of eggs per oviposition	25^{b}	92^{a}	1^{c}
Mean duration of incubation(days)	18^{b}±5	16^{b}±1	29^{a}±1
Mean number of hatched	43^{b}±31	78^{a}±37	3^{c}±2
Percentage of hatching(%)	64.60^{a}±24.05	68.41^{a}±22.40	62.50^{a}±11.18

The analysis of the results for the effect of 3 densities and 2 photoperiods on the fertility of the breeders showed that in breeding, the fertility was better in the density 50 snails / m² and the photoperiod 12L:12D.

The data on fertility and eggs characteristics for the three snails species in the 50 snails / m² density and the 12L:12D photoperiod are reported in Table 4, high animal densities can rarely be observed. Eggs are yellow with oval form. The dimensions and the weight of the eggs varied with species. *Archachatina ventricosa* (Gould) had larger eggs, and thus heavier ones, whereas *Achatina fulica* (Bowdich) had lighter and smaller size eggs. The total number of laying, the average number of eggs per laying, as well as the total number of eggs laid were higher for *Achatina fulica* (Bowdich) and weaker for *Archachatina ventricosa* (Gould).

The average duration of eggs incubation for *Achatina achatina* (Linné) and *Achatina fulica* (Bowdich) was half of the one for *Archachatina ventricosa* (Gould). The percentage of hatching was similar for the three species.

There was a significant difference ($p < 0.05$) between the mean values of the number of laying per month for *Achatina fulica* (Bowdich) and these for the 2 other species. As for the mean values of the monthly number of eggs per laying and the monthly total number of eggs laid, there was also a significant difference ($p < 0.05$) between the 3 species studied.

DISCUSSION

It results from literature that animals used were very young (12 months of age). According to Hodasi (1979), *Achatina achatina* (Linné) is mature at one year. The number of eggs observed per laying for this species increases from that age until 3 years old, then decreases. Waitkuwait *et al.* (1987) report that the sexual maturity of these snails is reached at 20; 10 and 9 months old, respectively, for *Achatina achatina* (Linné); *Achatina fulica* (Bowdich) and *Archachatina ventricosa* (Gould). For Upatham *et al.* (1988), *Achatina fulica* (Bowdich) is mature at 5 months old. Therefore, fertility could be a function of age, for snails.

The fertility of snails is influenced by climatic factors, especially the rain level. This factor greatly varies during the year (Bellard et al., 1977; Durand *et al.*, 1982). Seasons for reproduction and laying are found during the big dry season, and at the beginning of the big rainy season, as already observed by Hodasi (1979). In these periods, the rain level rises the hygrometry up, which in turn favours the reproduction, and thus the fertility. Takeda and Ozaki (1986) showed that the preferential relative humidity for snails is found between 75 and 95 % These values are only reached during the rainy seasons, which seem to explain the fact that the reproduction and the laying take place during these periods.

In breeding, the fertility of snails decreases with the increase of the animal density. With snails in natural environment, high animal can rarely be observed densities. According to Oosterhoff (1977), the increase of animal density provokes an important secretion of mucus, which, by retroaction, would inhibit the locomotion, and thus, indirectly, the reproduction and the fertilization. However our analyses indicate that

Fig. 3: Marking of the snails with black painting (half posterior of shells).
Fig. 3: Marcatura delle conchiglie con vernice nera (parte posteriore della conchiglia) e numeri bianchi.

this fatal effect of the animal density on the fertility of snails is not very noticeable for *Achatina achatina* (Linné) and *Archachatina ventricosa* (Gould), while it is so for *Achatina fulica* (Bowdich), when the animal density reaches 200 snails / m^2.

The fertility of snails in breeding is influenced by the photoperiod. Whatever the species may be, the 12 hours daylight / 12 hours dark treatment shows a fertility superior to that for the 0 hours daylight / 24 hours dark treatment. These results are in concordance with those of Rousselet (1982) and Hodasi (1982).

In breeding, at a density of 50 snails / m^2, a photoperiod of 12 hours daylight / 12 hours dark, a temperature and a relative humidity average of 26.6 ± 1.3°C and 82.9 ± 1.2 %, *Achatina fulica* (Bowdich) shows a fertility superior to that of both other species. This difference of fertility is essentially due to the fact that, for the three species, individuals hatched the same day do not reach sexual maturity in the same period. There is thus an age difference for the sexual maturity. This difference can also be due to a difference in food ingestion. Indeed, at 41g, *Achatina fulica* (Bowdich) would be already mature [17], while both other species are still in a pre-maturity phase. The number of eggs per laying increases with age for *Achatina achatina* (Linné), from the age of sexual maturity (Hodasi, 1979). This could explain the weakness in the performances observed for this animal.

Concerning the characteristics of the eggs and fertility parameters, our results confirm those of Hodasi(1979); Waitkuwait(1987); Upatham *et al.*, (1988); Zongo *et al.*,(1990). The durations of incubation and the percentages of hatching obtained in a substratum made up of frank earth and compost, in 2/1 propositions, can be improved by using humid cotton as substratum (Hodasi, 1979), or coconut shells (Upatham *et al.*, 1988). This difference in the duration of incubation and the percentage of hatching is due to the fact that the substratum used would contain parasites for the laying. This study shows that the bigger the eggs, the longer the duration of the incubation will be, and the weaker the fertility.

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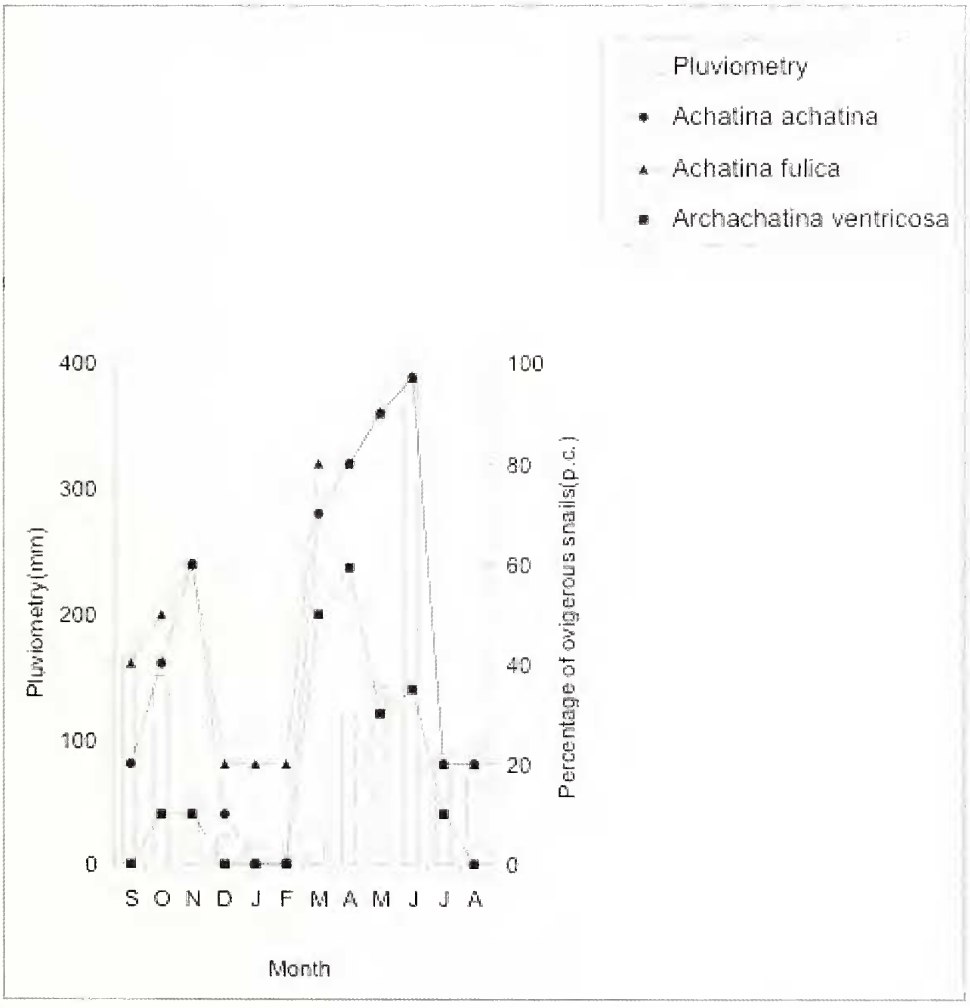

Fig. 4: Influence of pluviometry on the variation of monthly percentage of ovigerous snails in the year.
Fig. 4: Effetto della pluviometria sulla variazione della percentuale mensile di esemplari ovigeri nell'anno.

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